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Milk Fat Utilization in Foods

MILK FAT

It is only in the more recent years, when margarine has to a considerable degree displaced butter as a spread for bread, other fats have been substituted for milk fat in coffee whiteners and frozen desserts, and milk has been in surplus supply, that new and greater uses have been sought for milk fat. This fat, though it is the most essential component of cream, butter, and ice cream, must in many situations be considered and treated as a byproduct by the dairy industry.

The unique characteristic of milk fat is its delicate, pleasing flavor, evident in butter and in such products as candies, buttered popcorn, and bakery goods. The finest flavor is obtained when the milk fat-containing product has been freshly prepared from fresh milk. The flavor of heated, or "burnt," milk fat is also unique and is evident in foods fried in butter and in the heated milk fat known as ghee. On storage, milk fat has a strong tendency to deteriorate in flavor and because this tendency differs with the form in which the fat is stored, this chapter deals with the chemistry of milk fat deterioration, the prevention or minimizing of deterioration, and the manufacture of forms of milk fat suitable for holding in storage. Methods of production of cream, butter, and other sources of milk fat such as condensed, evaporated and dried whole milk are not described here. Only a brief general discussion of the use of milk fat in nondairy products is given; some specific products are discussed in Chap. 10.

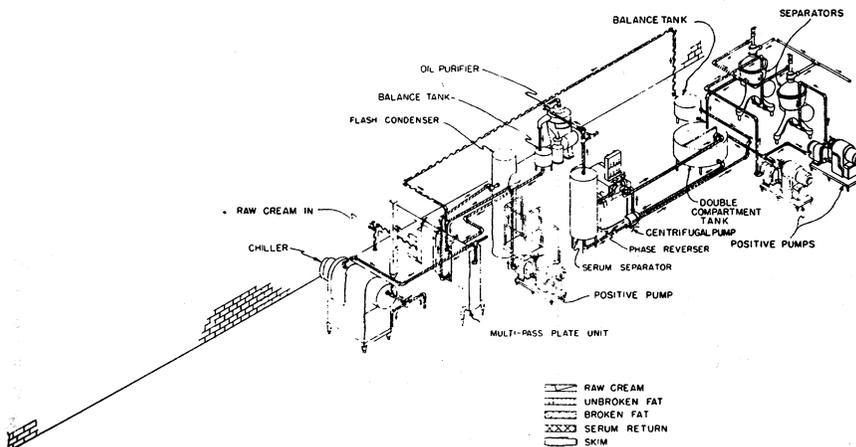
ANHYDROUS MILK FAT

In the international market there appears to be a consensus (Meister 1968) that products containing not less than 99.6% milk fat and less than 0.2% moisture should be designated anhydrous butterfat, anhydrous butter oil, or anhydrous milk fat, these terms to be employed interchangeably provided the products meet the composition requirement. In the United States, in the absence of legal definitions, two products are recognized usually—anhydrous milk fat and anhydrous butter oil. Anhydrous milk

fat is the product made from fresh whole milk, the manufacturing route being: fresh whole milk → cream → phase inversion → dehydration → anhydrous milk fat. Anhydrous butter oil is made from butter, either fresh or stored, which is converted to oil by melting, washing with water, and dehydrating. Anhydrous milk fat may be made from freshly churned butter, but this is not usually done.

The processing equipment is basically the same for the manufacture of the two anhydrous products: plate heaters; centrifugal separators and concentrators; ballast tanks; vacuum chambers; positive, centrifugal, and vacuum pumps; controls. The basic difference in procedure has to do with phase inversion. The fat emulsion in milk and cream is oil-in-water and must be inverted during the processing to a water-in-oil emulsion. This is necessary in order that the subsequent dehydration may be effective. In converting butter to anhydrous butter oil, inversion of phases is not required, since inversion has already taken place during the churning of the cream into butter.

Cream that is to be processed into anhydrous milk fat, is heated to 130° – 150° F and reconcentrated to 75–85% cream by centrifugal separation, prior to phase inversion. One method of phase inversion employs reverse flow at reduced capacity through a centrifugal pump. The violent churning action, which at low temperatures would convert cream into fine fat granules and serum, causes at the high temperature an inversion into a water-in-oil emulsion. A second method of phase inversion employs a pump of the homogenizer type (Gustafson 1968), called a “Phase Reverser” (Fig. 9.1). The 75–85% cream at 155°–165° F is fed by a centrifugal



Gustafson (1968)

FIG. 9.1. CONTINUOUS ANHYDROUS MILK FAT PROCESS (CAPACITY 2000 LB PER HR)

pump into the Phase Reverser. The pressure on the Phase Reverser is usually between 1200 and 1400 psi, differing for the types of cream being processed but precisely controlled. A third method employs the "Clarifixator" (Fjaervoll 1964), a combined centrifugal concentrator and emulsion breaker. Pasteurized 35-45% cream, at 150° F, is fed into the Clarifixator and an 80-85% cream is produced. This high-fat cream passes out of the spinning bowl into a paring chamber and impinges on the teeth of a cavitation disc. The violent action involved in the forming and breaking of gas bubbles causes phase inversion. The aqueous phase produced from this treatment should be passed through a separator to recover any fat that has escaped inversion.

The subsequent treatment of the crude oil produced from cream by phase inversion and that of the crude oil produced from butter by melting and gravity separation are the same. This crude oil is concentrated in a centrifugal separator to yield a 96-98% oil. The water from the separator is recycled to recover the small amount of oil present. The 96-98% oil is heated to 155° F and possibly as high as 190° F, and then spray injected into a vacuum chamber (29 in.) for final removal of moisture. During the vacuum treatment there is a drop in temperature directly related to the amount of moisture removed. The final product, containing not less than 99.8% fat and less than 0.1% moisture, is pumped from the vacuum chamber by a positive pump, cooled to 80° -90° F, and packed in tight containers.

GHEE

A product closely resembling the ghee of India is made in the United States for the purpose of converting surplus butter into a more stable form and one readily acceptable in certain foreign countries. Ghee is a nearly anhydrous butterfat having a characteristic flavor that is developed by heating the fat to a temperature high enough to "burn" the small amount of msnf present.

The following method is most generally employed in the United States for the conversion of butter into ghee (Anon. 1964). The butter is brought to room temperature, cut into pieces of convenient size, and placed in a steam-jacketed melting vat. The butter is stirred during melting. When melting is complete, hot water is added equal to approximately 50% of the volume of the butter. The heating and stirring are continued until the temperature of the fat-water mixture is at least 140° F, but not greater than 180° F. The mixture is then subjected to 1 or 2 centrifugal separations, preferably with a desludging-type machine for the first separation. The resulting oil should contain not more than 1% of moisture, salt and msnf. It is then heated in a closed system to at least 221° F, but not higher than

230° F, and held for 6 to 8 min. The hot oil is then discharged into a vat and 1% of lactic starter added. Evaporation of the remaining water is evidenced by gradually diminished bubbling. The oil is filtered to produce a clear liquid, cooled rapidly to approximately 85° F, and packaged with a minimum of agitation and exposure to air. The packaged ghee is then cooled slowly over a sufficient period to produce a granular structure.

The product made by this procedure has the typical ghee flavor in only a slight degree. Undoubtedly, the flavor could be strengthened by any one or more of the following means: increasing the temperature of heat treatment to 265°–285° F prior to the addition of the lactic starter; adding a greater amount of msnf in a more highly concentrated form than that in the lactic starter; more intimately mixing the starter and the hot oil by passing the hot oil through a throttled centrifugal pump while injecting the starter in such a way that it impinges on the center of the revolving impeller.

A method of making ghee directly from cream has been developed in the Dairy Products Laboratory of the U.S. Dept. of Agr. Sweet pasteurized 30–40% cream, preheated to 130°–145° F, is passed through a DeLaval Clarifixator at a rate of 3600 lb per hr, the back pressure on the centrifuge bowl being maintained at 45–50 psi. This treatment concentrates the cream to 70–80% milk fat, increases the temperature of the cream by 10°–15° F, and causes some phase inversion. This concentrated, partly destabilized cream is passed through the Clarifixator a second time. This passage accomplishes total phase inversion, increases the temperature by 5°–10° F, and results in a product consisting of approximately 96.5% milk fat, 0.9% msnf, and 2.6% moisture. Further moisture reduction is brought about by heating above 212° F in a closed system. A continuous heater of the swept- or scraped-surface design is employed, and the concentrate is throttled to atmospheric pressure or into a partial vacuum. After this treatment the product contains at least 99.8% milk solids and not more than 0.2% moisture. A final heating to 300°–305° F in the same heater causes the necessary “burning” of the remaining msnf, thus imparting the typical ghee flavor to the oil. A subsequent vacuum treatment removes most of the moisture from the product and lowers its temperature. Passage through a centrifugal separator removes the brown “dust” of the msnf and yields a clear, golden ghee containing more than 99.9% milk fat and less than 0.1% moisture. The ghee may be packed immediately in nearly sterile condition, or it may be cooled before packing to bring about the desired crystal formation. The various changes in temperature and the physical treatments encountered in the distribution of products of this type may alter their physical characteristics so much that sterile packing may be preferred to packing in granular condition.

STABILITY OF MILK FAT IN STORAGE

Since the characteristic of milk fat which makes it more attractive than most other fats and oils is its delicate, pleasant flavor, the retention of this flavor in storage is a matter of primary concern. The body, texture, or tactual qualities that butterfat imparts to manufactured products can be simulated, or can even be improved by various manufacturing techniques in products containing other fats. However, duplication of butter flavor in other fats has not been successful. Unfortunately, the flavor of milk fat is susceptible to deterioration on storage. Other flavors are produced which, even though often subtle, predominate over the bland flavor of fresh milk fat. Although storage instability in products containing milk fat may encompass deterioration of other types, such as bacterial spoilage, proteolytic breakdown, and physical changes, only flavor instability is included in the following discussion. In addition, flavor deterioration of milk fat must be regarded as the same phenomenon irrespective of the nature of the product, i.e., butter, butter oil, cream, etc. Although the presence of fat-globule membrane, other milk solids, and moisture can complicate the deterioration, this discussion will be restricted to changes in the lipid material.

The major defects that develop during storage of milk fat may be the result of either oxidative or nonoxidative changes, or both. To elucidate the nature of deterioration of these types, to identify the compounds responsible for the off-flavors that develop, and to find means for preventing their appearance has been the purpose of much research.

Nonoxidative deterioration involves the hydrolysis of triglycerides to yield normal fatty acids, beta keto acids, and gamma and delta hydroxy alcanoic acids. The keto acids may be decarboxylated to yield methyl ketones, and the hydroxy acids lactonized to yield lactones. Methyl ketones have been identified in butter oil, in dried whole milk, and in evaporated milk. They impart a definite flavor to milk or milk fat, and excessive amounts are responsible for off-flavors. The ketones that have been identified are the odd-numbered carbon ketones from C_3 to C_{15} , the most potent of which is 2-heptonone which has a flavor threshold of 0.7 ppm (Langler and Day 1964). Lactones are responsible for the coconut flavor of heated milk fat, and have been identified in butter oil, dried whole milk, dried cream, and evaporated milk. Lactones are very flavorful compounds and in small concentrations can impart a pleasing flavor to dairy products; but in large concentrations, impart a flavor that is often criticized as "lactone" or stale. The principal lactones evolved from milk fat are the C_{10} , C_{12} , C_{14} , and C_{16} delta lactones, which have a flavor threshold of 1-2 ppm in skim milk (Kinsella *et al.* 1967).

Oxidized flavors are the products of autoxidation of the unsaturated

fatty acids—mainly oleic, linoleic and linolenic—associated with the phospholipid and glyceride fractions of milk fat. The autoxidation mechanism is a chain reaction involving the formation of free radicals, then peroxides and hydroperoxides. The hydroperoxides are unstable and decompose readily to yield saturated and unsaturated aldehydes, ketones, and alcohols. Some of the terms applied to oxidized flavors are oily, painty, fishy, metallic, tallowy, and mushroom. The compounds responsible for these flavors are extremely potent and are detectable at very low concentrations. As an example, oct-1-en-3-one, which imparts a metallic off-flavor, is detectable in butter oil at 1 ppb (Stark and Forss 1962).

FACTORS AFFECTING STABILITY IN STORAGE

Effect of Heat Treatment

Available evidence has indicated that lactones and methyl ketones are formed as a result of heating milk fat, the latter in the presence of moisture (Schwartz *et al.* 1965). The quantity of methyl ketone formed is directly related to the temperature and time of heating (Schwartz *et al.* 1966). Temperatures in the vicinity of 212° F produce ketones rapidly, and even mild thermal exposure (104° F) produces them (Lawrence 1963). The precursors of lactones and ketones can be converted and removed from butter oil by steam stripping at a high temperature and a low pressure (Patton 1964). By carefully refining the fat in this manner, the lactone-ketone problem can be effectively eliminated. However, in products in which the steam stripping of the milk fat is not feasible, off-flavors due to ketones and lactones remain a problem.

Whereas heat treatment causes the formation of ketones and lactones in milk fat, it has, too, a beneficial effect in retarding deterioration of the oxidative type. The inhibitory effect of high-heat treatment on oxidative deterioration of the fat in fluid milk and other fat-containing products is well-established. The formation of sulfhydryls acts to lower the oxidation-reduction potential of the product and thus to prevent the oxidation of the fatty acids until after the sulfhydryls are oxidized (Josephson and Doan 1939). The heating of milk in excess of pasteurization prior to drying effectively stabilizes the flavor of air-packed dried whole milk during storage for 6 months at 80° F (Tamsma *et al.* 1962). Butter oil, made from butter which has been heated, is stable against oxidation, but when butter oil itself is heated it oxidizes rapidly. When dried skim milk is added to butter oil prior to heating, it exhibits a significant antioxygenic effect (Josephson 1943). The presence of milk solids during heating with the resulting formation of reducing substances is apparently the cause of the delaying of oxidation. This feature is responsible, apparently, for the

stability of flavor in ghee and ghee-like products, which may be stored at room temperature for extended periods without noticeable deterioration.

Effect of Storage Temperature

The effect of temperature of storage on the formation of ketones and lactones is similar to the effect of short-time heat treatment. It has been shown that significant amounts of ketones are produced at 104° F (Lawrence 1963). Similarly, milk made from butter oil that had been stored at 0° F for 8 wk was criticized as lactone, even though the milk scored much better than that made from butter oil stored at 80.6° F (Nelson *et al.* 1966). In general, ketones and lactones will be produced during storage in quantities in direct relationship to the temperature of storage. Investigations have shown that low storage temperatures inhibit the development of oxidized flavors in butter and dried whole milk. In a study in which milk fat was held at various temperatures from 17° to 112° F, oxidized flavors were observed at all temperatures. However, higher storage temperatures had the effect of accelerating the development of oxidized flavors (Hamm *et al.* 1968). The inhibition of oxidative deterioration in milk held at high temperatures has been attributed to a lowering of the oxygen content as a result of bacterial activity. Of the products which are stored for fat content, cream is the only one in which bacterial growth is possible, and in cream it is of doubtful value, since the number of bacteria necessary to decrease the oxygen materially would be sufficient to cause deterioration of other types.

Effect of Moisture

It has been demonstrated that moisture is necessary for ketone formation (Van der Ven *et al.* 1963), and its exclusion during heating or storage is a significant factor in the stability of milk fat. When butter oil, which had been dried by means of calcium hydride, was heated for 24 hr at 214° F, no detectable ketone was produced, and only a relatively small quantity of carbonyls was produced after 9 days (Schwartz *et al.* 1965). The absence of moisture may be a reason for the excellent storage stability claimed for anhydrous butter oil. Moisture content of foam-dried milk also has an influence on its storage stability, although the effect is related to other factors (Aceto *et al.* 1965; Tamsma and Pallansch 1964).

Effect of Oxygen

The removal of oxygen, or its replacement with an inert gas, has proved an effective means of retarding oxidation in most fat-containing dairy products. It is claimed that tallowy flavor in butter oil could be prevented by reduction of the oxygen to less than 0.8% of the volume of the oil

(Schaffer *et al.* 1946). In dried whole milk, improvement in stability in storage has been obtained by packing with inert gas at a 3–4% level (Greenbank *et al.* 1946), by packing with inert gas containing 0.5 to 1.0% oxygen (Lea *et al.* 1943), and by reducing the level of oxygen to 0.1% (Tamsma *et al.* 1961). Adequate deaeration lessened flavor deterioration in concentrated sweetened cream that was stored for 6 months at 40° to 70° F (Anderson *et al.* 1961). It has been concluded that the time required for the production of oxidized flavors is inversely proportional to the oxygen concentration.

Effect of Antioxidants and Ascorbic Acid

The use of antioxidants in dairy products is academic, since regulations prohibit the addition of these compounds. Investigations on the prevention of oxidized flavors by use of antioxidants are somewhat inconclusive. Whereas no beneficial effect on cold-storage butter could be shown by use of nordihydroguaiaretic acid, butylated hydroxytoluene, or butylated hydroxytoluene plus isopropyl citrate (El-Negoumy and Hammond 1962), antioxidants were completely effective in stabilizing against oxidative deterioration of butter oil which had been previously steam deodorized (Wyatt and Day 1965). Only lauryl gallate, of several antioxidants investigated, considerably improved the flavor stability of foam-dried whole milk stored at 80° F (Tamsma *et al.* 1963).

The chemistry involved in the use of ascorbic acid in milk has been reviewed (Parks 1965). Ascorbic acid is little used in stabilizing the flavor of dairy products for a number of reasons, one being that in low concentrations it promotes oxidation, but in high concentrations inhibits it. However, the flavor of cream and concentrated sweetened cream has been shown to be improved after 3 months by the addition of 50 mg of ascorbic acid per liter (Bell *et al.* 1962).

Effect of Hydrogenation

Storage stability of butter oil may be definitely improved by trace hydrogenation and winterization, as measured by organoleptic evaluation and peroxide values. The improvement is due to decreasing the percentage of the highly unsaturated acids, linolenic and arachidonic. The level of unsaturation may be restored by winterization. The incorporation of butter oil so treated into reconstituted whole milk results in considerable improvement in flavor stability (Mukherjea *et al.* 1966).

MEANS OF IMPROVING STABILITY IN STORAGE

It is obvious that, in order to obtain maximum improvement in storage stability, the factors which favor the two types of deterioration must be

controlled or eliminated. Nonoxidative deterioration is caused by heat and moisture. It can be controlled by the employment of low heat in the absence of moisture, or eliminated by generating the objectionable compounds by heat and removing them by distilling at low pressures. Oxidative deterioration is favored by the presence of oxygen and by high storage temperatures. Heating in the presence of msnf, which causes the formation of reducing substances, delays the onset of oxidative deterioration. Therefore, the combination of the processing treatments mentioned, with low-temperature storage in the absence of air, should result in products with optimum stability against flavor deterioration.

MILK FAT IN FOODS

The more common uses of milk fat, besides as butter, are in association with other milk components, as in ice cream and other frozen desserts. These contain other ingredients, nondairy in origin. In the baking and candy industries, butter is associated with high quality and these quality products utilize large quantities of milk fat, both in the form of butter and as other dairy products. In the food manufacturing field, there is a tendency to upgrade the quality of some products by the use of milk fat in the recipes. These upgraded products are the result of research by food manufacturers, butter manufacturers, and food research organizations, both private and public. Butter is most often the chief selling point. No doubt other products composed of milk fat—anehydrous milk fat, butter oil, ghee, or ghee-like products—would serve equally well and fit more conveniently into modern food manufacturing processes, but butter is the usual source of milk fat partly because of legal restrictions. Regulations do not permit other high-milk fat products to be substituted in products labeled as containing butter.

Sauces

The incorporation of butter sauces in frozen and canned vegetables is a comparatively recent development (Anon. 1966). Literally dozens of brands of these products are now available to the American consumer, and these account for large amounts of milk fat in the form of butter. Many of the recipes for these sauces, which are varied to adapt them to different vegetables, have been developed by food processors with the aid of butter manufacturers. Weckel *et al.* (1967) have published results of research on the canning of vegetables in butter sauce. The use of sauces of milk fat other than butter is a possible development in this field.

Spreads

The term spread defines the product as a semisolid substance of such consistency that it can be made to form a layer on a solid food, such as

bread. Butter is, itself, a spread and milk fat is a component of most fat-containing spreads except margarine. Spreads should not be confused with salad dressings, which are fluid or semifluid and contain oil as their fatty component. Most fat-containing spreads other than butter are patented and therefore are in controlled production. The problems on the manufacture of spreads lie in obtaining a product of the desired spreadability and of physical and chemical stability in storage or on grocery shelves. Obviously, they should be packed in airtight containers and sterilized. Though most of the fat-containing spreads on the market are blends containing cheese, olives, nuts or similar edible products, a different type of spread is made by blending vegetable fats and milk fat. The blending may be done by churning and yields a spread similar to butter in appearance. Flavor and spreadability may be controlled at will by the choice of fats and by blending procedures.

The products described above utilize only comparatively small amounts of milk fat, but with the transfer of much of food preparation from the kitchen to the factory, considerable increase is to be expected (Coulter 1966). Other products utilizing milk fat are described in Chap. 10.

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